

## Planting Date Effects on Winter Triticale Dry Matter and Nitrogen Accumulation

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### ABSTRACT

Addition of triticale ( $\times$ *Triticosecale* Wittmack) into more diversified cropping systems could provide valuable economic and environmental benefits to producers in the U.S. Corn and Soybean Belt. To maximize triticale value, research was conducted to identify planting dates that allowed maximum dry matter production and N capture. Winter triticale was planted at 10-d intervals from 15 September to 15 October at three Iowa locations: central, northeast, and southwest for two growing seasons: 2002–2003 and 2003–2004. Aboveground dry matter production, N concentration, and N removal were greater at southwest Iowa than central and northeast Iowa. Dry matter production decreased as planting was delayed from late September to late October. Nitrogen accumulation at any time during the spring and summer was greater for September–than October-planted triticale in 2002–2003. At the end of the 2002–2003 season, mid-September-planted triticale had accumulated 37% more N than mid-October-planted triticale. In 2003–2004, total N capture occurring by early May was less for late-October-planted triticale than the other three planting dates, but there were no differences in N capture among the four planting dates from late May until maturity. Dry matter production was greatest when at least 300 growing degree days (GDDs) (base 4°C) accumulated between planting and 31 December. These results suggest that triticale should be planted in September to maximize spring forage yield and N accumulation although later planting dates would provide a higher quality forage if harvest was not delayed into late spring and summer.

ADDITION OF TRITICALE into more diversified cropping systems for the U.S. Corn and Soybean Belt could reduce soil erosion (Dabney, 1998; Kaspar et al., 2001), capture residual soil N (Meisinger et al., 1991; Meisinger and Delgado, 2002), provide high quality forage for extended grazing periods (Baron et al., 1999; Lyon et al., 2001), and provide an additional grain crop. Soils are generally fallow during late fall and early spring in the corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] cropping system used on most of the row crop acres in this region. This increases the potential for erosion, mineralization of N, and leaching of residual nitrate. Successful utilization of the late-fall and early-spring periods requires that a crop be able to establish rapidly and grow vigorously under the cool conditions that occur after harvest of summer crops (Dinnes et al., 2002). Rapid crop establishment would protect against soil erosion that becomes problematic following crops that leave the soil with little residue cover, such as corn silage, soybean, and vegetable crops. Ample growth could

also capture excess plant available N left after primary crops and decrease the potential of NO<sub>3</sub> leaching into ground water. In studies done with rye (*Secale cereale* L.) cover crops, reductions in the mass of leached N ranged from 59 to 77% compared with no cover crop (Meisinger et al., 1991). Production of winter triticale could provide fall and spring forage supplies when other sources are unavailable (Lyon et al., 2001) and allow grain to be harvested and used as a high quality swine feed (Bruckner et al., 1998). To capture these potential benefits from triticale, proper agronomic production practices must be determined.

Planting date is one of the most important management factors involved in producing high-yielding small grains (McLeod et al., 1992; Dahlke et al., 1993). However, growers may have to delay seeding of winter small grains until after the optimal date to accommodate harvest of preceding full-season summer crops. Numerous studies show that delayed planting of winter wheat (*Triticum aestivum* L.) decreased forage yields in the subsequent spring and summer (Corns, 1959; Thill et al., 1978; Baron et al., 1999). When seeding of winter wheat in Alberta was delayed from late August to late September, forage yield at the dough stage was reduced by 30% (Corns, 1959). Winter wheat planted in early September in Washington had shoot weights at anthesis that were 13 Mg ha<sup>-1</sup> greater than wheat planted one month later (Thill et al., 1978). Baron et al. (1999) concluded that early fall seeding of winter wheat, triticale, and rye in Alberta resulted in earlier forage availability and spring dry matter yield was closely related to GDDs from seeding to freeze-up in the fall.

When harvesting small grains for forage, a compromise must be made between quality and quantity since yield and nutrient levels are greatly influenced by plant maturity. As small grains mature, fiber concentration increases while crude protein concentration decreases (Bolsen, 1984), resulting in reduced feeding value. Wheat N concentration has been shown to decrease with time during the growing season because of slower N assimilation rates relative to C (Knowles and Watkin, 1931; Daigger et al., 1976). Crude protein concentration in winter wheat forage grown in Nebraska averaged 310 g kg<sup>-1</sup> (49.6 g N kg<sup>-1</sup>) at fall harvest and spring jointing but dropped to 170 g kg<sup>-1</sup> (29.8 g N kg<sup>-1</sup>) when harvested at boot stage (Lyon et al., 2001). Date of planting has a significant effect on crude protein levels in wheat forage. Winter wheat planted early (23 to 28 August) had lower crude protein at all harvest stages than subsequent planting dates (3 to 9, 10 to 19, and 21 to 30 September), which tended to have similar crude protein levels (Lyon et al., 2001).

Winter triticale has potential to be a valuable grain,

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Triticale

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**Abbreviations:** GDD, growing degree day.

forage, and/or cover crop in the U.S. Corn and Soybean Belt because it contains valuable traits from its parent species, wheat and rye, that allow for production of quality forage and grain while limiting soil erosion and N leaching. However, there are few established agronomic guidelines for growing winter triticale in this region. Proper planting date may be one of the most important factors determining the success of winter triticale because of the rapid temperature decline following harvest of full-season summer annuals. The objectives of this study were to determine adaptation of winter triticale in Iowa and optimum planting dates for dry matter production and total seasonal N accumulation.

## MATERIALS AND METHODS

Winter triticale was grown during the 2002–2003 and 2003–2004 seasons at three Iowa locations. Trials were conducted in central Iowa at the Iowa State University (ISU) Bruner Farm near Ames (42° N, 93°36' W), the ISU Northeast Research and Demonstration Farm near Nashua (43° N, 92°30' W), and in southwest Iowa at the USDA Deep Loess Research Station near Treynor (41°12' N, 95°36' W) in 2002–2003 or at the ISU Armstrong Research and Demonstration Farm near Lewis (41°18' N, 95°6' W) in 2003–2004. Predominate soil types were Nicollet loam (fine-loamy, mixed, mesic Aquic Hapludolls) at the Bruner Farm, Kenyon loam (fine-loamy, mixed, mesic Aquic Hapludolls) at Nashua, Monona silt loam (fine-silty, mixed, mesic Typic Hapludolls) at Treynor, and Marshall silty clay loam (fine-silty, mixed, mesic Typic Hapludolls) at Lewis.

Triticale was seeded using a no-till drill (Tye model 2007, AGCO Corp., Lockney, TX) with 10 rows spaced 20.3 cm apart. Soybean was the previous crop at all locations. No tillage was performed unless previous production practices left the soil surface unsuitable for planting. Minimum tillage (field cultivation) was performed at Treynor in 2002–2003 and Lewis in 2003–2004. The seeding rate was 330 seeds m<sup>-2</sup> for all years and locations. Plot size was 5.9 by 15.2 m. Targeted planting dates were 15 September, 25 September, 5 October, and 15 October. Actual planting dates are listed in Table 1. Due to late soybean harvest at Nashua in 2002, only the latter three dates could be planted. In 2002–2003, cultivars Trical 815 and DANKO Presto were planted at Ames and Nashua while only Trical 815 was planted at Treynor. For 2003–2004, Trical 815 and DANKO Presto were planted at Ames, Nashua, and Lewis. Nitrogen fertilizer, in the form of urea, was applied at 56 kg ha<sup>-1</sup> at all locations during the spring 2002 before initial green-up of the triticale. In spring 2004, 39 kg ha<sup>-1</sup> of ammonium nitrate was applied at Lewis because soybean residue was removed before planting.

Daily maximum and minimum temperatures were recorded

during the growing season (planting to 31 December and 1 March to harvest) at each location using an on-farm weather station. Mean climatic conditions were obtained from the Iowa Environmental Mesonet (2004) for each site. Daily GDD (4°C base temperature) were calculated by using the equation:

$$\text{GDD} = [(\text{daily maximum temp.} + \text{daily minimum temp.})/2] - \text{base temp.}$$

## Data Collection

Spring dry matter samples were taken starting the first week of May and every 3 wk thereafter (Table 1). Two 0.203-m<sup>2</sup> samples cut 2.5 cm above the soil surface were taken from each plot, combined, dried at 60°C for 48 h, and weighed to determine dry matter production of each plot. Plots were staged according to Zadoks et al. (1974) at each dry matter sampling date.

Grain was harvested with combines, equipped with on-board electronic weighing systems, from areas ranging from 3.66 to 4.57 m wide by 15.24 m long, depending on the combine platform size. Grain subsamples (approximately 2000 g) were taken during the combine harvest to determine moisture concentration. Moisture concentration was determined using a grain analysis computer (Model GAC2100, Dickey-John, Auburn, IL). Final grain yields were adjusted to 135 g kg<sup>-1</sup> moisture. Straw samples were collected from the swath created by the combine.

Subsamples (100 g) from spring dry matter samples were analyzed for N and C concentration. Straw (100 g) and grain (20 g) samples were analyzed for N and C. Dry matter and straw samples were ground first in a Wiley mill (Arthur Thomas Co., Philadelphia, PA) fitted with a 3.0-mm screen. The dry matter and straw samples were further ground using a UDY cyclone sample mill (Model 3010-030, UDY Corp., Fort Collins, CO) fitted with a 1.0-mm screen. Grain samples were ground once using the UDY cyclone sample mill. Nitrogen and C concentration of the samples were determined by combusting 200 mg at 950°C in a LECO (Model CHN-2000, LECO Corp., St. Joseph, MI) analyzer (AOAC Int., 2000, p. 26–27).

## Statistical Design and Analysis

The experimental layout was a randomized complete block with four replications. Data was analyzed within years using SAS (SAS Inst., Inc., Cary, NC). Two- and three-way interactions of location, planting date, and cultivar were analyzed for 2003–2004. Interactions were not analyzed for 2002–2003 because of missing data for Trical 815 at the southwest location and mid-September planting at the northeast location. Statistically significant interactions were subjected to further ANOVA using the slice command of Proc Mixed.

**Table 1. Dates of planting, dry matter collection, and grain harvest for winter triticale grown at three Iowa locations in two growing seasons.**

Activity	2002–2003			2003–2004		
	Central	Northeast	Southwest	Central	Northeast	Southwest
<b>Planting</b>						
Mid-Sept.	13 Sept.	–	16 Sept.	17 Sept.	15 Sept.	15 Sept.
Late Sept.	24 Sept.	23 Sept.	25 Sept.	26 Sept.	25 Sept.	24 Sept.
Early Oct.	8 Oct.	7 Oct.	9 Oct.	7 Oct.	6 Oct.	5 Oct.
Mid-Oct.	17 Oct.	16 Oct.	18 Oct.	16 Oct.	16 Oct.	15 Oct.
<b>Dry matter sampling</b>						
Fall	12 Nov.	18 Nov.	14 Nov.	21 Nov.	20 Nov.	24 Nov.
Spring 1	8 May	9 May	7 May	4 May	5 May	3 May
Spring 2	29 May	30 May	28 May	25 May	26 May	24 May
Spring 3	19 June	20 June	18 June	16 June	15 June	14 June
Spring 4	10 July	11 July	9 July	7 July	7 July	6 July
Grain harvest	22 July	25 July	14 July	15 July	27 July	14 July

**Table 2. Mean daily temperature (°C) averaged for 2-wk periods for the locations and growing seasons of the study.**

Date	2002–2003			2003–2004			Mean temperature†			
	Ames‡	Nashua	Treynor	Ames	Nashua	Lewis	Ames	Nashua	Treynor	Lewis
	°C									
1 Sept. to 14 Sept.	21.4	20.7	22.4	19.5	19.6	19.8	20.6	18.6	20.5	19.3
15 Sept. to 28 Sept.	15.3	14.5	16.0	13.4	13.2	14.7	16.8	14.7	16.6	15.4
29 Sept. to 12 Oct.	14.3	13.8	15.0	13.6	12.5	14.5	14.4	12.4	14.2	13.0
13 Oct. to 26 Oct.	4.6	3.8	5.1	11.3	9.8	12.2	11.9	9.6	11.6	10.2
27 Oct. to 9 Nov.	3.0	2.8	3.7	1.5	0.7	2.4	7.7	5.4	7.1	5.8
10 Nov. to 23 Nov.	1.9	1.0	2.4	4.4	3.5	5.7	4.5	1.6	4.0	2.6
1 Mar. to 14 Mar.	–5.9	–6.9	–3.3	3.0	1.2	3.6	1.4	–1.9	1.3	–0.1
15 Mar. to 28 Mar.	8.4	7.6	7.2	6.4	5.8	7.1	4.4	1.3	4.5	3.1
29 Mar. to 11 Apr.	5.9	3.3	6.8	6.6	6.1	7.9	8.1	5.7	8.2	7.4
12 Apr. to 25 Apr.	12.2	11.4	13.6	12.1	11.0	12.9	11.6	9.6	11.5	10.5
26 Apr. to 9 May	12.8	12.5	13.9	13.8	12.8	15.2	14.4	12.7	14.4	13.3
10 May to 23 May	13.9	13.5	14.3	17.0	16.0	17.4	17.0	15.6	17.1	16.2
24 May to 6 June	17.0	16.4	17.8	17.5	16.9	18.3	18.6	17.4	19.0	18.1
7 June to 20 June	20.4	19.9	20.7	21.2	20.9	21.3	21.7	20.3	22.0	21.1
21 June to 4 July	22.5	22.3	23.3	18.8	18.6	19.6	23.1	21.7	23.5	22.5
5 July to 18 July	22.3	21.0	24.8	21.0	20.4	22.1	24.3	22.5	24.4	23.4
19 July to 31 July	22.0	21.5	23.5	20.8	20.4	21.5	24.4	22.4	24.4	23.3

† Mean temperatures from 1951 to 2004 were obtained from the Iowa Environmental Mesonet. Data for Ames, Nashua, Treynor, and Lewis were obtained from stations at Ames, Charles City, Glenwood, and Atlantic, respectively.

‡ Seasonal temperature data were obtained from on-farm weather stations at Ames, Nashua, Treynor, and Lewis.

Repeated measurements of dry matter, N concentration, and N accumulation for individual experimental units were used to predict response to thermal time in 200-GDD increments using Proc Mixed (Littell et al., 1996). A second-order polynomial line was fit to dry matter and N accumulation responses to thermal time. A Type III exponential function (Sit and Poulin-Costello, 1994) was used to fit N concentration response to thermal time. Predicted experimental unit values at each 200-GDD increment were compared for statistical significance using an *F* test. Proc Mixed was also used to compute *F* tests for main effects of location, planting date, and cultivar on grain yield, grain N concentration, grain N accumulated, and straw N concentration. Tukey's test was used to make mean comparisons for significant main effects (Steel and Torrie, 1980).

Relative dry matter yields for both seasons of the study were calculated as a percentage relative to the mean of the highest-yielding planting date within a location and growing season. The critical amount of GDDs needed to obtain maximum relative dry matter production was determined by the

procedure described by Cate and Nelson (1971). Proc Reg of SAS was used to fit lines to the populations on each side of the critical level of GDDs obtained from the Cate–Nelson test. Significance level for all statistical tests was *P* = 0.05.

## RESULTS AND DISCUSSION

### Weather Conditions

Climatic conditions (Tables 2 and 3) were more favorable for high triticale forage and grain yields during 2002–2003 than 2003–2004. The 2003–2004 growing season was predominated by cool and moist conditions that increased the presence of *Septoria* leaf blotch (*Septoria* spp.) at all locations. Mean fall temperatures were slightly below normal, and fall precipitation was near normal in both 2002 and 2003. Early growing conditions were near normal in the spring of each year. Temperatures during grain fill (June to mid-July) were normal

**Table 3. Average precipitation for 2-wk periods for the growing seasons and locations of the study.**

Date	2002–2003			2003–2004			Mean precipitation†			
	Ames‡	Nashua	Treynor	Ames	Nashua	Lewis	Ames	Nashua	Treynor	Lewis
	cm									
1 Sept. to 14 Sept.	0.3	0.8	0.9	3.8	2.2	1.5	2.2	2.1	2.7	3.0
15 Sept. to 28 Sept.	3.0	4.0	1.1	4.9	2.5	3.4	1.8	2.0	2.3	2.0
29 Sept. to 12 Oct.	4.2	3.4	6.3	0.7	0.9	0.8	1.8	1.6	1.8	1.8
13 Oct. to 26 Oct.	1.9	1.1	1.1	0.8	0.6	0.9	1.7	1.7	2.0	1.9
27 Oct. to 9 Nov.	1.3	0.9	1.0	1.2	0.3	3.9	1.6	1.3	1.9	1.7
10 Nov. to 23 Nov.	0.1	0.4	0.0	0.0	0.0	0.0	1.4	1.3	1.6	2.1
1 Mar. to 14 Mar.	0.0	0.0	0.1	0.0	0.0	0.0	1.2	1.1	1.3	1.4
15 Mar. to 28 Mar.	0.0	0.0	1.0	0.0	0.0	0.0	1.4	1.2	1.7	1.6
29 Mar. to 11 Apr.	0.6	0.7	1.4	0.0	0.0	0.0	1.4	1.3	1.6	1.4
12 Apr. to 25 Apr.	0.8	3.7	2.6	4.5	4.3	4.5	1.7	1.7	1.8	1.7
26 Apr. to 9 May	10.1	11.6	9.0	1.5	2.2	3.4	1.9	1.8	2.1	2.0
10 May to 23 May	1.8	1.9	2.7	11.5	18.0	10.9	2.0	2.0	2.2	2.0
24 May to 6 June	2.3	5.6	3.0	5.5	7.3	5.2	2.1	1.7	2.5	2.1
7 June to 20 June	1.7	3.7	2.5	5.0	4.2	4.4	2.5	2.0	2.5	2.3
21 June to 4 July	2.6	7.1	3.5	4.2	5.7	6.8	2.8	2.5	3.0	2.4
5 July to 18 July	5.6	5.0	2.0	2.7	7.5	4.3	2.7	2.3	2.5	2.4
19 July to 31 July	2.8	0.9	0.6	0.5	3.2	3.9	2.2	2.3	2.5	2.1
Precipitation totals§	38.9	50.6	38.7	46.6	59.0	53.9	32.4	29.9	35.6	33.8

† Mean precipitation from 1951 to 2004 was obtained from the Iowa Environmental Mesonet. Data for Ames, Nashua, Treynor, and Lewis were obtained from stations at Ames, Charles City, Glenwood, and Atlantic, respectively.

‡ Seasonal precipitation totals were obtained from on-farm weather stations at Ames, Nashua, Treynor, and Lewis.

§ Combined precipitation for the 1 September to 23 November and 1 March to 31 July periods.

**Table 4.** Mean square data from the ANOVAs for dry matter accumulation, N concentration, and N removal of winter triticale at 200 growing degree increments during two Iowa growing seasons.

		Accumulated growing degree days (°C)†					
Source	df	400	600	800	1000	1200	1400
Dry matter accumulation							
2002–2003‡							
Location (L)	2	6.75**	55.94***	79.71***	79.52***	52.91***	16.09***
Date (D)	3	36.12***	45.73***	38.77***	31.45***	20.33***	7.71***
Cultivar (C)	1	1.93	2.10	0.99	0.12	0.26	1.63
2003–2004							
L	2	115.22***	220.26***	255.03***	351.29***	453.94***	172.00***
D	3	57.68***	29.52***	17.73***	15.66***	14.00***	3.69*
L × D	6	0.75	0.86	1.39	1.85	2.04	1.10
C	1	0.84	0.18	0.31	1.53	7.01**	9.21**
L × C	2	3.78*	3.91*	3.75*	4.76*	5.91**	2.18
D × C	3	0.10	0.33	0.27	0.30	2.18	4.52**
L × D × C	6	0.99	0.33	0.32	0.51	1.05	1.03
N concentration							
2002–2003							
L	2	95.57***	79.35***	56.01***	44.00***	37.28***	33.10***
D	3	23.65***	6.95**	2.73	1.93	1.87	1.97
C	1	0.47	0.69	0.62	0.56	0.52	0.49
2003–2004							
L	2	60.05***	84.90***	72.22***	60.76***	53.26***	48.24***
D	3	47.07***	28.16***	13.35***	7.28***	4.58**	3.20*
L × D	6	2.58*	0.85	0.48	0.52	0.60	0.67
C	1	0.00	0.22	0.42	0.51	0.56	0.59
L × C	2	1.48	0.54	0.15	0.04	0.01	0.00
D × C	3	0.48	0.12	0.18	0.28	0.34	0.39
L × D × C	6	1.05	0.71	0.49	0.40	0.35	0.32
N removed							
2002–2003							
L	2	38.16***	69.55***	78.97***	80.37***	68.97***	27.33***
D	3	12.49***	10.79***	8.29***	7.36***	7.22***	5.12**
C	1	0.30	0.04	0.00	0.00	0.04	0.28
2003–2004							
L	2	205.72***	280.54***	260.87***	293.79***	313.54***	87.09***
D	3	7.81***	0.66	0.07	0.19	0.19	1.37
L × D	6	0.72	0.96	1.55	1.68	1.02	0.68
C	1	0.86	0.77	0.80	1.42	3.15	2.56
L × C	2	0.63	0.32	0.17	0.31	1.19	1.58
D × C	3	0.23	0.38	0.24	0.08	0.49	1.51
L × D × C	6	0.38	0.48	0.44	0.40	0.38	0.39

\* *F* test significant at the 0.05 level.\*\* *F* test significant at the 0.01 level.\*\*\* *F* test significant at the 0.001 level.

† Growing degree days (base 4°C) accumulated after growth resumed in the spring. Daily growing degree days were calculated as [(daily maximum temp. + daily minimum temp.)/2] – base temp.

‡ Two- and three-way interactions were not analyzed for 2002–2003 because of missing data for one cultivar at one location and one planting date at another location.

in 2003 and below normal in 2004. Precipitation during the period of May to mid-July was above normal both seasons. However, the bulk of the precipitation for this period occurred in early May for 2003 while it came in mid-May and continued to be above normal through June in 2004.

### Location Effects

The two winter triticale cultivars were better adapted to southwest than central and northeast Iowa for forage production and N capture. Southwest locations consistently had greater dry matter yields, N concentration, and N removal at each 200-GDD increment than either central or northeast locations (Table 4, Fig. 1). More dry matter was produced at the central than northeast location during the 2002–2003 growing season while in 2003–2004, more dry matter was produced at the northeast location. Nitrogen concentration was similar at the central and northeast locations in both years. Nitrogen accumulation generally reached a maximum at 1000

GDDs after 1 March (Stage 80) at all locations. Total N removal ranged from 52 to 115 kg ha<sup>-1</sup> and 95 to 161 kg ha<sup>-1</sup> in 2002–2003 and 2003–2004, respectively. Triticale grown at southwest Iowa removed 18.4 and 24.1 more kg N ha<sup>-1</sup> than the next highest site in 2002–2003 and 2003–2004, respectively. Similar amounts of N were removed at the central and northeast locations during 2002–2003. In 2003–2004, N removal was greater at the northeast than the central location from 600 to 1400 GDDs after 1 March. The central location had poor drainage, possible soil compaction, and suspected low N fertility, which resulted in minimal tillering, low dry matter yields, and poor N capture.

The southwest location had the greatest grain N concentration, grain N removal, and straw N concentrations in both growing seasons (Table 5). The amount of N removed in the grain from southwest Iowa was double that removed at the lower of the other two sites in both years. This was due to a combination of greater grain yields and greater N concentration at the southwest



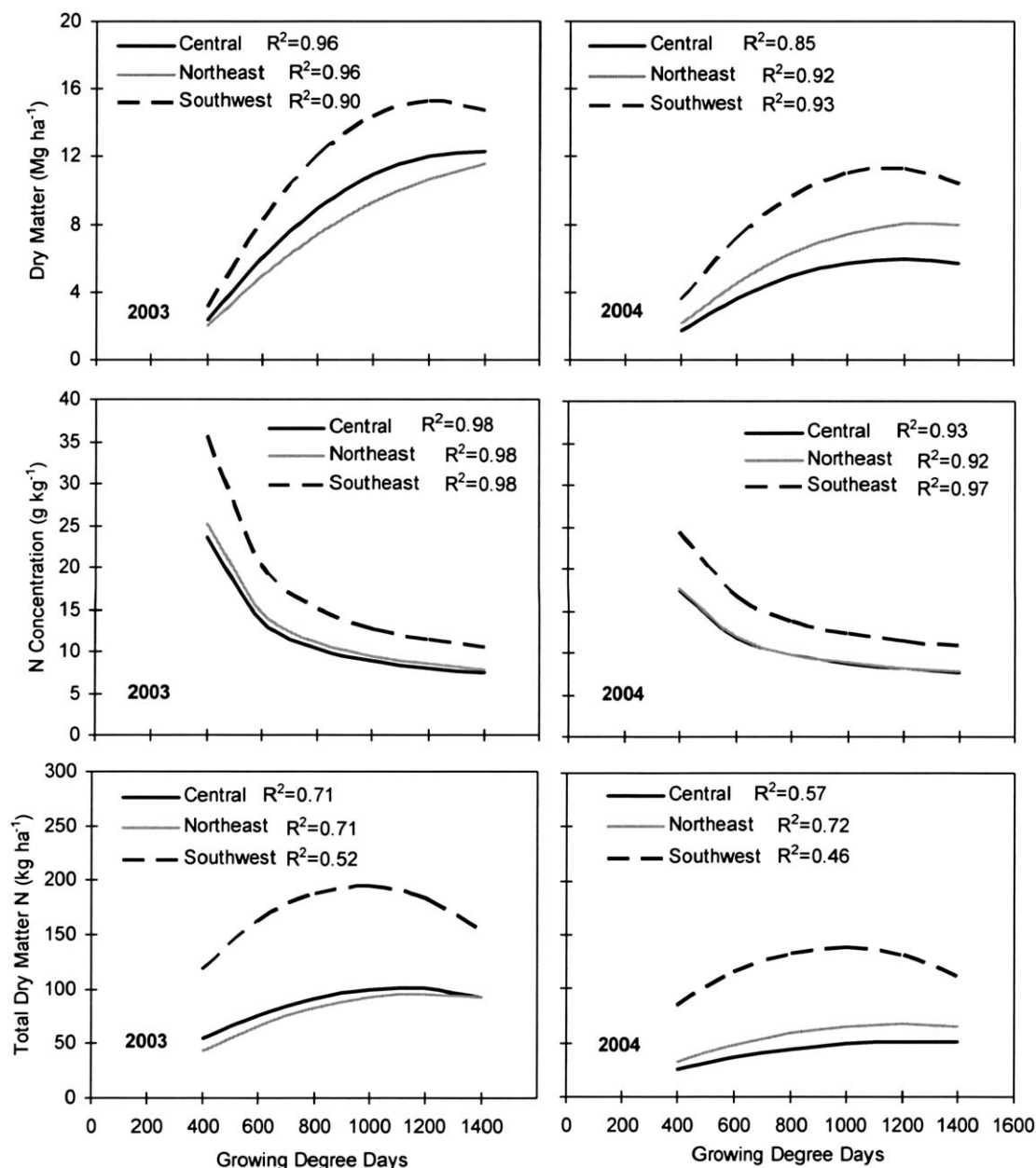


Fig. 1. Location effects on spring and summer dry matter accumulation, N concentration, and N removal of winter triticale in Iowa during two growing seasons. Growing degree days were calculated from 1 March using a base temperature of 4°C.

location when compared with the other two locations. Northeast Iowa had slightly greater grain N concentration than central Iowa in 2002–2003, but greater grain yield resulted in more grain N removed at central Iowa. Greater grain yields at northeast Iowa in 2003–2004 resulted in more grain N removal when compared with central Iowa even though grain N concentration was similar at the two sites. These results suggest that grain yield was more important for determining differences in grain N removal between the central and northeast locations than was grain N concentration.

### Optimum Planting Date

September planting was critical to maximizing total spring forage production and total N accumulation of

winter triticale in these central U.S. Corn and Soybean Belt locations (Table 4, Fig. 2). Dry matter production was reduced with each successive 10-d delay in planting after 25 September. Limited fall growth of late-planted triticale likely restricted leaf area (Watson, 1958; Thill et al., 1978) and solar radiation interception (Puckridge and Donald, 1967), resulting in reduced rate of spring regrowth. Final dry matter yield was maximized when at least 300 GDDs accumulated between planting and 31 December (Fig. 3). A linear decrease in yield occurred when less than 300 GDDs accumulated while there was no change in yield with more than 300 GDDs. These results agree with the 300 GDDs needed before 31 December for maximum grain yield (Schwarte, 2004). Based on 30-yr average GDD accumulations, maximum

**Table 5. The main effects of location, planting date, and cultivar on winter triticale grain yield, grain N concentration and accumulation, and straw N concentration at three Iowa locations during two growing seasons.**

Parameter	Grain yield		Grain N		Straw N
	Mg ha <sup>-1</sup>	g kg <sup>-1</sup>	kg ha <sup>-1</sup>	g kg <sup>-1</sup>	
	2002–2003				
Location					
Central	3.97b†	15.6c	62.0b	3.76b	
Northeast	3.05c	16.7b	51.3c	3.70b	
Southwest	4.97a	21.6a	104.9a	5.41a	
Planting date					
Mid-Sept.	4.12ab†	17.8ab	76.6a	4.34a	
Late Sept.	4.32a	17.5b	77.7a	4.22a	
Early Sept.	3.87b	18.1ab	71.0ab	4.10a	
Mid-Oct.	3.48c	18.5a	65.6b	4.51a	
Cultivar					
DANKO Presto	3.79b†	18.0a	70.2a	4.49a	
Trical 815	4.10a	17.9a	75.3a	4.09a	
	2003–2004				
Location					
Central	1.75b	16.9b	29.2c	2.63b	
Northeast	2.58a	17.7b	45.6b	2.70b	
Southwest	2.68a	22.2a	59.3a	4.28a	
Planting date					
Mid-Sept.	2.46a	18.6a	46.5a	2.71b	
Late Sept.	2.50a	18.8a	47.3a	2.96b	
Early Sept.	2.36a	18.9a	45.0ab	3.23ab	
Mid-Oct.	2.02b	19.5a	40.0b	3.86a	
Cultivar					
DANKO Presto	2.26b	18.8a	42.9b	3.19a	
Trical 815	2.41a	19.0a	46.5a	3.21a	

† Means for treatments within a parameter followed by the same letter are not significantly different according to Tukey's test ( $P = 0.05$ ).

forage yields would be achieved by planting on or before 30 September, 26 September, and 6 October in central, northeast, and southwest Iowa, respectively.

Nitrogen concentration was similar for mid- and late-September-planted triticale throughout the spring and summer in 2002–2003 (Table 4, Fig. 2). At 400 GDDs, September-planted triticale had lower N concentration than early-October-planted triticale, which had lower N concentration than mid-October-planted triticale. At 600 GDDs, there was no longer a difference in N concentration between the two October planting dates; however, September-planted triticale had lower N concentration than October-planted triticale. From 800 until 1400 GDDs, there were no differences in N concentration among the four planting dates. A location and planting date interaction at 400 GDDs resulted from differences between N concentration at the central and northeast locations for the October planting dates but not the September planting dates. Nitrogen concentration was 2.5 and 3.1 g kg<sup>-1</sup> greater at the northeast than the central location for the early- and mid-October plantings, respectively. In 2003–2004, mid-September-planted triticale had lower N concentration than late-September-planted triticale at 400 GDDs, early-October-planted triticale from 400 to 800 GDDs, and mid-October-planted triticale from 400 to 1400 GDDs. Late-September-planted triticale had lower N concentration than early-October-planted triticale from 400 to 600 GDDs and mid-October-planted triticale from 400 to 1200 GDD. Early-October-planted triticale had lower N concentration than mid-October-planted triticale from 400 to 800 GDDs.

There was no difference in total N removal between mid-September- and late-September-planted triticale at

any time in 2002–2003. Mid-September planting resulted in greater N removal than early- and late-October planting throughout the spring and summer growth period. Nitrogen removal for late-September-planted triticale was greater than early-October-planted triticale from 400 to 800 GDDs and mid-October-planted triticale from 400 to 1200 GDDs. There were no differences in total N removal between early- and mid-October-planted triticale. At the end of the 2002–2003 season, mid-September-planted triticale had accumulated 37% more N than mid-October-planted triticale. In 2003–2004, total N removal was less for late-October-planted triticale than the other three planting dates at 400 GDDs after 1 March. There were no differences in N removal among the four planting dates from 600 to 1400 GDDs.

Grain N concentration increased by 1.0 g kg<sup>-1</sup> when planting was delayed from late-September to mid-October in 2002–2003 (Table 5). Planting date did not significantly affect grain N concentration in 2003–2004 or straw N concentration in 2002–2003. However, straw N concentration increased with delayed planting in 2003–2004. September planting resulted in 18 and 17% greater N removal in the grain than mid-October planting in 2002–2003 and 2003–2004, respectively. Lower grain yield for mid-October- compared with September-planted triticale was a more important determinant of lower N removal than grain N concentration.

It is well known that as plants mature, N concentration, and thus protein, decreases (Daigger et al., 1976; Karlen and Whitney, 1980). This response was well represented with winter triticale in our study. Seasonal N accumulation was about 50% complete at 400 GDDs (Stage 30); however, dry matter accumulation was less than 20% complete. The continued dry matter accumulation that occurred after the majority of N uptake resulted in a dilution of plant N concentration. Nitrogen concentration decreased rapidly with each GDD increase from 400 to 800 GDDs. Nitrogen concentration declined much less with each GDD increase after 800 GDDs. Early-season N concentration was greater for late-planted triticale. Nitrogen concentration became equal for all planting dates at 800 GDDs after 1 March (Stage 65) in 2002–2003. However, differences in N concentration between mid-September- and mid-October-planted triticale occurred throughout the entire growing season in 2003–2004. The low straw N concentrations as compared with grain N were due to remobilization of N into grain that occurs during grain filling of small grains (McNeal et al., 1966; Karlen and Whitney, 1980; Bauer et al., 1987).

### Cultivar Differences

The ANOVA for main effects of cultivar and interactions of cultivar with location and planting date is presented in Table 4. Trical 815 produced more dry matter than DANKO Presto throughout the spring and summer growth period at the central location in 2003–2004. The dry matter difference between the two cultivars was 0.45 Mg ha<sup>-1</sup> at 400 GDDs but increased steadily as GDDs accumulated and was greatest at 1400 GDDs when Trical 815 produced 1.09 Mg ha<sup>-1</sup> more dry matter

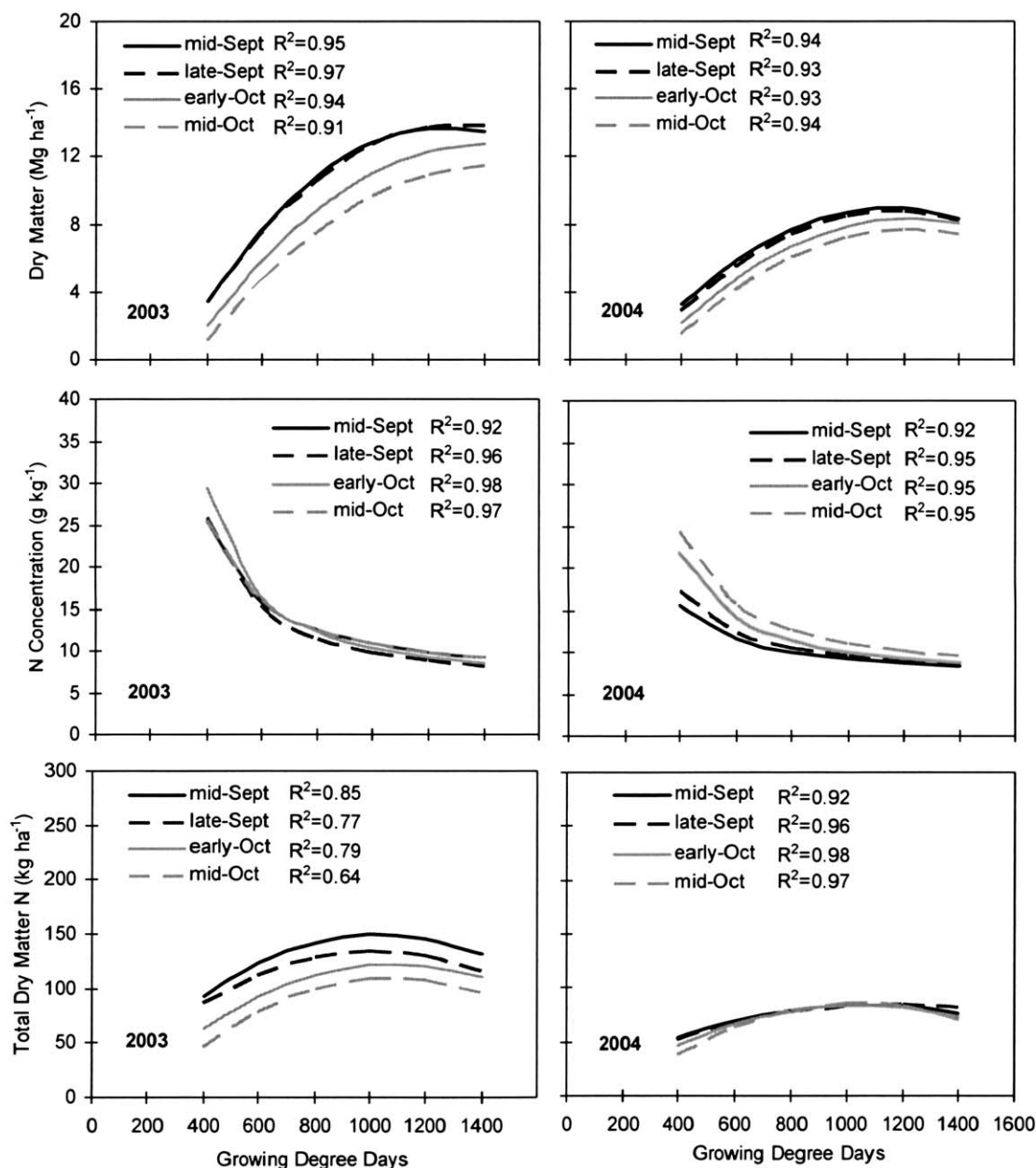


Fig. 2. Planting date effects on spring and summer dry matter accumulation, N concentration, and N removal of winter triticale in Iowa during two growing seasons. Growing degree days were calculated from 1 March using a base temperature of 4°C.

than DANKO Presto. There were no differences in dry matter production between the two cultivars at the northeast and southwest locations. Trical 815 produced 1.67 and 0.86 Mg ha<sup>-1</sup> more dry matter than DANKO Presto at 1400 GDDs for the mid-September and early-October plantings, respectively. There were no differences between the two cultivars for the late-September and mid-October plantings.

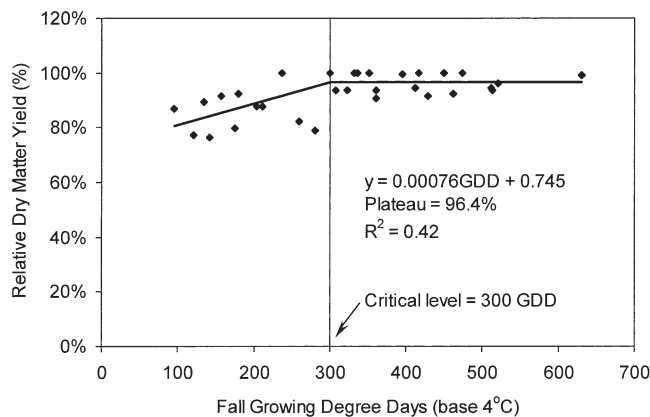
Greater N concentration and grain yield for Trical 815 in 2002–2003 resulted in 41% greater grain N removal when compared with DANKO Presto. In 2003–2004, 21 and 8% more N was removed in the grain of Trical 815 than DANKO Presto at the central and southwest locations, respectively. These N removal differences were mainly due to variation in grain yield

rather than N concentration. There were no differences in N removal or grain yield between the two cultivars at the northeast location.

### Implications for Winter Triticale Addition to Cropping Systems

Producers wanting to get full yield potential from a subsequent full-season summer annual crop, such as corn or soybean, would need to terminate or harvest triticale by mid-May. Based on historical mean temperatures, 400, 350, and 475 GDDs have accumulated by 16 May in central, northeast, and southwest Iowa, respectively. In the current study, winter triticale planted in September at central and southwest locations was in the jointing and boot stages at 400 and 475 GDDs and





**Fig. 3.** Effect of planting date on relative dry matter yield of winter triticale grown over two growing seasons at three Iowa locations. Relative yields are based on mean final dry matter yield of the highest-yielding planting date within each location and growing season. Growing degree days were calculated beginning at planting. Critical level was obtained using the Cate–Nelson test to separate the data into two populations. Regression then fitted lines to the two populations.

produced 4 and 5 Mg ha<sup>-1</sup> dry matter with N concentrations of 19 and 22 g kg<sup>-1</sup>, respectively. Dry matter accumulated by mid-May was nearly 2 Mg ha<sup>-1</sup> greater for September- than October-planted triticale. Delaying harvest of September-planted triticale until inflorescence emergence (Stage 50; 600 GDDs) resulted in 4.5 to 7 Mg ha<sup>-1</sup> dry matter in central and northeast Iowa and 8 Mg ha<sup>-1</sup> in southwest Iowa. The N concentration of triticale at this stage was 13 to 16 g kg<sup>-1</sup> in central and northeast Iowa and 17 to 20 g kg<sup>-1</sup> in southwest Iowa. Based on historical mean temperatures, inflorescence emergence would occur on 31 May, 5 June, and 25 May in central, northeast, and southwest Iowa, respectively. Past research suggests that planting corn or soybean on these dates in central and southwest Iowa would result in at least 90% of full yield potential (Farnham, 2001; Whigham et al., 2000). Planting corn or soybean on 5 June in northeast Iowa would provide about 80% of full yield potential.

Seasonal N accumulation in triticale dry matter serves as a measure of N removal from the soil. Nitrate leaching is most problematic on fallow soils in the early spring months when rainfall amounts are high. Therefore, the amount of residual N triticale can capture from the soil to prevent NO<sub>3</sub> from entering ground and surface water is important. Triticale was not tested against other species, but it appears to be efficient in N uptake during early spring. There are a couple of ways that winter triticale could be used for N capture in central USA grain cropping systems. It could be planted after harvest of summer annual crops in the fall and terminated before or shortly after planting of summer annuals in the spring. Our study indicates that winter triticale used this way could capture significant amounts of residual N. More than 50% of triticale N uptake occurred by mid-May, and nearly 75% of N uptake had occurred by late May. The full N capture potential of winter triticale could be exploited by harvesting it as a grain crop in mid- to late July. September planting would likely be required to

maximize N capture of winter triticale. Planting date influenced the amount of N removal in 1 of 2 yr in our study. The impact was quite large considering that 37% more N was taken up by mid-September- than mid-October-planted triticale.

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